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SALINE WATER RESEARCH PROGRAM

REPORT

OF

INTERIOR AND INSULAR AFFAIRS COMMITTEE

HOUSE OF REPRESENTATIVES

ON

HEARINGS

FOR THE

PURPOSE OF REVIEWING PROGRESS MADE UNDER THE SALINE WATER RESEARCH PROGRAM

APRIL 1957

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House of Representatives

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SALINE WATER RESEARCH PROGRAM

The House Interior and Insular Affairs Committee, acting pursuant to its responsibility for surveillance of the research program to develop economically feasible processes for conversion of saline or salt water to fresh water, held hearings to review progress under this research program on March 7 and 8, 1957. The hearings were before Congressman Aspinall's Subcommittee on Irrigation and Reclamation.

This report discusses the need for this research program, the purpose and need for the hearings, the legislative history, the Department's annual reports, the information developed by the hearings, and the committee's conclusions.

NEED FOR THIS RESEARCH PROGRAM

Conversion or demineralization of saline or sea water is a process for reclaiming water from otherwise unusable sources by removing dissolved salts. This conversion process is looked upon today as a possible source of meeting our ever-expanding water needs. Its use would supplement the short supplies along coastal areas as well as in those inland areas where water is becoming increasingly saline to a point where it can no longer be used.

The need for additional water has already become acute in many areas of the Nation and the situation is continually becoming more critical. The Nation's water needs are increasing even more rapidly, proportionately, than the ever-increasing population and expanding industry because of the per capita increase in the amount used. A half century ago, when there were 85 million of us in the United States, we were using, for all purposes—including domestic, industrial, and agricultural—an average of only 450 gallons of water per day per capita. Today we have a population of 170 million and are using 1,500 gallons each per day. By 1975 it is estimated that we will be using more than 2,000 gallons per day per capita.

Since 1900, water consumption in the United States has increased almost seven times. It is estimated that by 1975 our present water requirements will have almost doubled again. No longer can 170 million Americans, estimated to become more than 200 million by 1975, take for granted that ample water supplies will be available wherever and whenever needed. By 1975 it is estimated that the Nation, now using 250 billion gallons of water a day, will be using 450 billion gallons daily or more than 10 times the amount used in 1900.

Industrial use is expected to require a large portion of this increase and already plans for industrial expansion have been delayed or abandoned because the water needs could not be met. The amount of water required for processing materials in our industrial developments is somewhat staggering—for instance, it takes 70,000 gallons of water to make 1 ton of paper, 65,000 gallons to make 1 ton of steel,

24,000 gallons to produce 1 ton of synthetic rubber, and 500 gallons to produce 1 yard of woolen goods.

At the present rapid rate of increase in our water requirements, it is expected that the time will come when the remaining isolated sources of natural fresh water in our rivers, lakes, wells, etc., will probably be prohibitively expensive to collect and store and distribute to places where it is needed.

Of course, the first step in the years ahead is to reduce our excessive waste of water. This can be done by controlling pollution of our streams, conserving and reusing available water so far as possible, controlling and using additional floodwaters, and emphasizing better management of present uses of water for all purposes.

However, even with development of our natural water sources so far as that is feasible and adoption of measures to conserve our limited supplies, there will be need for new and additional sources of water—thus, the need for this research program to develop economically feasible processes for converting sea water and other saline water to fresh water of a quality for municipal, industrial, and even agricultural uses.

It is expected that, as our studies and research progress and our development and use of remote and isolated sources of fresh water become increasingly more expensive, processes for converting sea and saline water to fresh water will become competitive, economically, with development of natural water sources. The time when this will occur will, of course, differ in different areas. With some areas already planning to transport water hundreds of miles, it is hoped that this research program will bring salt or saline water conversion into competition with conventional methods of supplying water at an early date.

PURPOSE AND NEED FOR THE HEARINGS

The objective of these hearings, called by Chairman Engle to review this program with officials of the Department of the Interior, was to accomplish four specific purposes. First, the committee wanted to determine just where we stand at the present time with respect to finding economic means of converting saline or salt water to fresh water. Second, the committee wanted to determine if the views of the Department were consonant with those of Congress as to the degree of urgency to be given the program. Third, the committee wanted to know what measures the Department had taken to speed up the program in response to the congressional expression of urgency set out in the act of June 29, 1955, and the related House and Senate reports. Fourth, the committee wanted to know if additional legislation was needed or would be of assistance in meeting the objectives of the program at an earlier date. Chairman Engle's letter to Assistant Secretary of the Interior Aandahl scheduling the hearings follows:

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
HOUSE OF REPRESENTATIVES,
Washington, D. C., February 27, 1957.

Mr. FRED G. AANDAHL,
Assistant Secretary of the Interior,
Department of the Interior,
Washington, D. C.

DEAR MR. AANDAHL: In these days of drought and water shortages when more and more importance is being placed upon our limited water resources. when the President makes special mention in his state of the Union message that water is rapidly becoming our most precious natural resource, when it is fast becoming apparent to all that we must develop new sources of fresh water, I believe it appropriate that we determine just where we stand in the program to find ways and means of economically converting sea water to fresh water.

This committee and I personally have followed closely the progress of this program since it was authorized in 1952 and made the responsibility of the Secretary of the Interior. Two years ago we amended the Saline Water Act of 1952 providing an additional $8 million and flexibility of operations. We hoped that this additional authority would reflect a speedup in meeting the objectives of the program. As you may recall, the conference report on the legislation carried this statement of the House managers:

"The Nation's rapidly increasing population and expanding industry, with the corresponding rapidly increasing needs for water, the critical water situations that have developed in many areas in recent years, and national and international conditions in this atomic age all reflect the imperative need for speeding the objectives of this program. It may become necessary within the term of this program for many areas to depend on salt or saline water conversion for a water supply. Ways and means must be found without undue delay for economically converting salt or saline water to fresh water. The program cannot be allowed to drift along without producing concrete results, and it is expected that with the expanded implementation of the saline-water program authorized by this legislation results will be obtained."

The Senate report on the legislation carried similar language.

Nevertheless, recent reports do not indicate the progress hoped for. Several on the committee have expressed disappointment. There appears to be a feeling that the program is not receiving the degree of urgency it deserves or which the Congress expected.

In view of the above, I believe it would be mutually beneficial for the committee, because of its responsibility for surveillance of this program, to review the program with you. Congressman Aspinall, chairman of the Reclamation Subcommittee, has set aside March 7 and 8 for this purpose. The committee would like to discuss the program with you and the program director. Also, if possible, the committee would like to question Mr. W. L. Badger or representative relative to the long tube vertical evaporator which he proposes, and perhaps representatives from 1 or 2 additional firms whose research appears to be producing favorable results.

Would you please advise me with respect to your appearance. Also, I would appreciate any comments you may have in this connection.

Sincerely yours,

CLAIR ENGLE, *Chairman.*

BACKGROUND AND HISTORY OF LEGISLATION

The conversion of salt or saline water to fresh water for limited uses—for instance, aboard ships—is not new. However, attempts to make such conversion competitive with other means of supplying water for general use in water-short areas is new. The Federal Government's activities in this field date back to 1952. The initial legislation providing for this research program was enacted on July 3, 1952, and is known as the Saline Water Act of 1952. It was about this time that the Nation started to become more conscious of the importance of our water resources to its economic strength. This initial act, authored by Congressman Engle, recognizes the Federal Government's responsibility for an adequate supply of water

to the Nation and for finding new sources of fresh water. It authorized the appropriation of $2 million to carry on a 5-year research program with the objective of developing economically feasible processes for converting sea water and other saline water to fresh water of a quality suitable for municipal, industrial, agricultural, and other beneficial uses. The legislation made the Secretary of the Interior responsible for the research program. Initially, it was envisioned that the program would be accomplished by (1) federally financed contracts with private scientists and engineers, educational institutions, scientific organizations, and engineering firms for conducting scientific research; (2) encouraging development of saline water conversion processes by correlating and coordinating efforts in this field; and (3) stimulating the interests of private and business organizations and individuals in the program. The legislation provided for annual reports to Congress on the progress that was being made.

Subsequent to enactment of this legislation, there was widespread interest in the program and the Department of the Interior negotiated numerous contracts for research work. The results of these initial research projects were encouraging with respect to eventually developing municipal and industrial water supplies for cities or areas with a salt or saline water supply source. Results were favorable also to making brackish water usable for agricultural purposes. At the same time, because of certain limiting factors such as the cost of energy, it became pretty clear that it would be a long time before any conversion process became competitive with conventional methods of supplying irrigation water or even municipal or industrial water except under exceptional circumstances. It was concluded that no single process would provide fresh water for all purposes at all locations and under all circumstances. This made it desirable that several different principles, processes, and combinations of processes be investigated and developed concurrently. In addition, because the cost of energy was obviously a limiting factor in any process, research in the field of solar energy was initiated. Also, there has been a close watch on developments in the use of nuclear energy in the hope that in the future this may be the answer to reducing energy costs.

In early 1955, with still 2 years remaining of the authorized 5-year program, it became apparent that amendments to the basic act were needed. First, it became clear that 5 years was not enough and that the program period should be extended without waiting until the 5-year period was up in order to assure uninterrupted continuation of the program. Next, there developed a very definite need for using existing Federal scientific facilities to accomplish a limited amount of technical assistance, especially in making unbiased comparisons of processes and for confirming research results. The third need for amending the basic act was to provide additional funds. Initially, most of the research and development on processes was done on a relatively small-scale laboratory basis and only nominal expenditures were required. As individual processes showed promise, more expensive research, including field tests, was required.

Congressman Engle's bill to amend the Saline Water Act of 1952 was introduced in January 1955, and the Interior and Insular Affairs Committee held hearings on February 16 and 17. The legislation passed the House on May 16, 1955, later passed the Senate, and was approved by the President on June 29, 1955. This amending legis-

lation extends the period of the research program to 10 years plus 3 additional years for compiling the results and reporting thereon, increases the amount authorized to be appropriated from $2 million to $10 million, and permits research to be carried on to a limited extent in existing Government laboratories. In addition, it specifically provides close cooperation and coordination with the Atomic Energy Commission and the Civil Defense Administration.

Since the initiation of this program, the Nation's water situation has become continually more critical. The Nation's rapidly increasing population and expanding industry with the corresponding rapidly increasing needs for water, the critical water situations that have developed in many areas in recent years, and national and international conditions in this atomic age, all reflect an imperative need for speeding the objectives of this program. It was for these reasons that the implementing congressional reports to the 1955 amending legislation made clear the position of Congress that the matter of accomplishing the objectives of this program was urgent and that ways and means must be found without undue delay for economically converting salt or saline water to fresh water.

ANNUAL REPORTS OF THE DEPARTMENT

Summary statements from the annual reports of the Department of the Interior submitted to Congress pursuant to the 1952 basic act are set out in the appendix to this report. These statements, covering the years 1952 through 1956, summarize the progress which has been made under this research program since it was initiated. Detailed information with respect to the various categories of processes being studied or with respect to specific processes may be obtained from reports in the committee's files or from the Office of Saline Water, Department of the Interior.

INFORMATION DEVELOPED BY THE HEARINGS

In the 2 days of hearings the committee heard Assistant Secretary of the Interior Fred G. Aandahl, under whose direction the saline water research program has been placed; Mr. David S. Jenkins, Director, Office of Saline Water; Mr. Allen Cywin, one of the specialists on Mr. Jenkins' staff; Dr. George Löf, a contractor in the field of solar energy and solar distillation; and Mr. W. L. Badger, a contractor and developer of the Badger Cycle, a multiple-effect evaporation process. These hearings are being printed as Serial No. 5.

Mr. Aandahl described briefly the Department's handling of the program. He pointed out the appropriation difficulties which the Office of Saline Water had experienced and expressed his belief "that the progress of the program has been consistent and correlated with the funds appropriated." He expressed the hope that progress could be accelerated with the funds in prospect beginning in the coming fiscal year 1958. Secretary Aandahl did not comment on the urgency of meeting the objectives of the program.

Mr. Jenkins discussed in more detail than the Secretary the administration of the program by the Department of the Interior, including the organization of his Office. He discussed briefly the processes that had been studied and the status or disposition of each. He discussed

in more detail a few of the more promising processes such as the Hickman still, a rotary vapor-compression distillation process; the Badger Cycle, a multiple-effect evaporation process; the electrolysis process of Ionics, Inc.; solar distillation; and freezing.

Mr. Jenkins expressed the opinion that no process was yet ready for large-scale testing, He indicated that such large-scale testing probably would be beyond the scope of the present legislation and would require specific authorization, and that he expected such specific authorization might be required for several projects within the next 1 to 3 years, including the Hickman still, the Badger Cycle, a freezing cycle, and a solar still.

In view of the concern and disappointment that had been expressed by the committee relative to indicated increases in conversion costs for the various processes rather than the decreases hoped for, Mr. Jenkins discussed this matter at some length. He explained that initially the estimated costs of conversion given in the Department's reports were taken from the best available sources, were not based upon any uniform standard procedure, and were for the most part not supported. Recent cost estimates are based upon a standardized cost estimating procedure and are believed by the Department to be realistic.

Mr. Jenkins summarized his presentation to the committee as follows:

> Therefore, in the 5 years that we have been working, with $2 million spent so far, or about one eight-thousandths of the amount, which I understand is about $16 billion, that has been spent on atomic energy, we feel that we have made some progress. That progress can be summed up as follows:
>
> The field of processes has been reduced from 19 general groups to 6.
>
> No. 2, four processes have been advanced to the pilot-plant stage.
>
> No. 3, there have been several processes which have been advanced to the engineering stage.
>
> No. 4, there have been developed 3 wholly new principles to separate salt water, all of which are expected to reach the engineering stage in 1 or 2 years.
>
> No. 5, work has been initiated on two wholly new principles.
>
> No. 6, we are now initiating and planning to begin in July, active exploration, possibly in cooperation with the AEC, of combinations of atomic energy and salt-water conversion.
>
> And No. 7, there has been stimulated a very significant number of private investigations by private firms.
>
> No. 8, we are cooperating with a large number of foreign countries; and I believe there has been a great deal of goodwill generated.

Questioned with respect to several optimistic statements relating to this research program by Secretary Seaton and other Department officials and whether they were justified, both Secretary Aandahl and Mr. Jenkins generally supported the statements. Secretary Aandahl stated:

> * * * And I can very easily visualize that some time within the reasonable future—and when I say that I am thinking of 5 years or 10 years, something like that—these processes will be reduced to a cost where water will be immediately in demand for industrial and municipal uses, and perhaps on some land very near the ocean, where specialized and high-priced crops are being raised, even for irrigation purposes.
>
> I do not visualize any early transmission of water halfway across the continent, but I do visualize a time in the not too distant future when purified sea water will be used quite extensively near the borders of the ocean.

* * * * * * *

For example, if a community near the seacoast that is now dependent upon the flow of a river for its supply of water can have that supply replaced by purified sea water with very limited transmission costs, then the river water that is going a long way down to the seaboard town could be used in areas nearer its source; and by short pipelines going out from that river system, areas deep in the heart of the country could be reached. It does not involve the piping of the sea water clear across the continent; but there is the possibility of exchange that can come with a reasonable price for purifying sea water. And I do not think that the statements that have come from the Secretary's Office, which have been intended to be visionary and which have been intended to give some hope to the American people, have gone far enough so that we need to be disturbed by their implications. * * *

To a question as to whether he could see anything in the foreseeable future whereby waters could be economically transferred from the Pacific Ocean to the Colorado River Basin for irrigation purposes, as intimated in recent statements of Secretary Seaton, Mr. Jenkins replied, "It might very well be transferred by exchange."

In response to questioning, Mr. Jenkins expressed the opinion that everything possible was being done to speed up progress on those promising processes which presently appear to warrant large-scale testing. He specifically discussed the Badger Cycle and the difficulties experienced in getting delivery of equipment required to carry on the studies with respect to the scaling problem. He estimated that it would be at least next November before the equipment is erected and that the Department estimates a year of experimentation and study after that will be required. In other words, it will be about 2 years more before this process is ready for large-scale testing and only then if the scaling problem is solved.

Asked which of the processes looked most favorable at the present time, Mr. Jenkins stated that he could not venture a guess. He did mention, however, for sea water conversion, the Badger Cycle and a freezing process presently being studied by the Carrier Corp., and, for brackish water, the Ionics, Inc., electrodialysis process and the osmionic process being studied by Southern Research Institute.

Mr. Aandahl commented favorably on the proposal advanced by Chairman Engle that a cooperative Federal-State program, whereby the States that would initially benefit would participate financially in the research program, might expand interest in the program and speed up accomplishment of the objectives at an earlier date.

Mr. Jenkins indicated no immediate need for additional legislation. He discussed the need for a central research and testing center but stated that the Department considered that it had the authority for this. He indicated, however, that additional authorization would be required for large-scale testing of specific processes when and if the research studies justified such development.

Mr. Allen Cywin discussed the Hickman still, which is a rotary vapor-compression distillation process. This equipment was described as involving an important advance in distillation techniques. An experimental model designed to produce about 25,000 gallons of water per day from sea water has been built by the Badger Manufacturing Co. and is in operation at the company's plant in Cambridge, Mass. It will be moved to a seashore location in the near future for extensive testing.

Dr. George Löf, who has been a contractor with the Office of Saline Water for several years in connection with solar energy and solar distillation, discussed the solar distillation principle and the technical

aspects of the solar still that is being installed in San Diego. The one big advantage of this process is the fact that the energy, which comes from the sun, is free. The process has the disadvantages of high installation cost and requirement for large installation areas to produce appreciable quantities of water. Recent advances in producing low-cost plastic materials for use in connection with this equipment may produce more favorable results. The results from the testing at San Diego, which will get underway shortly, will determine the future course of action on this process.

Mr. W. L. Badger, contractor with the Office of Saline Water and developer of the so-called Badger Cycle, a multiple-effect evaporation process, made a statement to the committee on this process.

Mr. Badger is a chemical engineer with many years experience with evaporators and evaporator projects. His statement was very optimistic with respect to the possibilities of the long tube multiple-effect evaporator for economic sea water conversion. He indicated that the only major problem in the way of large-scale testing related to whether scaling from the salts in sea water could be prevented in the tubes. While recognizing this as a problem, he expressed confidence that it could be solved. He described the present tests to be conducted for this purpose and agreed with Mr. Jenkins' estimate that it would take approximately 2 years to complete these tests. He also agreed that large-scale testing should await a resolution of the scaling problem.

Mr. Badger discussed the possibility of operating this multiple-effect evaporator in conjunction with a steam electric generating plant by using exhaust steam for operating the evaporator. He was particularly enthusiastic about this combined operation as a means of reducing conversion costs.

Mr. Badger indicated that after the scaling problem is resolved, the next step should be a plant with a capacity in the order of 17 million gallons per day for large-scale testing. He estimated that the engineering design and other preconstruction activities for such a plant would require about a year. The estimated conversion cost given by Mr. Badger was 30 cents per thousand gallons, or about $100 per acre-foot, based upon the combined evaporator-steam plant development with energy being sold for 4 mills per kilowatt-hour. He pointed out that revenue from the electric energy was a big factor in the overall cost of conversion and he estimated that if the electric energy could be sold for 6 mills, the water would be free.

In response to questioning, neither Mr. Badger, Dr. Löf, nor Mr. Cywin thought that there was much that could be done to speed the accomplishment of the objectives of the program.

CONCLUSIONS

The first specific purpose which the committee hoped to accomplish by these hearings was to determine just where we stand in this research program to find economic means for converting saline or salt water to fresh water. Unfortunately, we are not as far along as the committee had hoped. The committee feels that it is unfortunate also that conversion cost trends have been upward and in the direction away from the objective of finding economic conversion processes. The committee did not receive any information to support recent optimistic statements by Secretary Seaton or even to support statements to the committee by Assistant Secretary Aandahl and Mr. Jenkins during the hearings.

For instance, the committee finds no support, in the information presented to it, for Secretary Aandahl's statement, quoted earlier in this report, that he visualized that within 5 or 10 years, conversion costs will be reduced to the point where fresh water by conversion processes will be immediately in demand for industrial and municipal uses and perhaps some agricultural use near the ocean. An examination, for example, of the schedule for further research work on the Badger multiple-effect evaporator, which appears to be further advanced than any other promising process, leads to the conclusion that, at best, under the Department's schedule, it will be 6 or 7 years before large-scale testing could get underway and that it would be a considerable time later, assuming very favorable results from the tests, before there would be any interest or demand for general use. The Department estimates 2 years before it will be known whether large-scale testing is warranted. Such large-scale testing would require additional congressional authorization and this will take time. Another year—according to the estimate given the committee—would be required for engineering design and other preconstruction activity and an additional 2 or 3 years would be required for construction.

The committee cannot agree with the statements of either Secretary Aandahl or Mr. Jenkins with respect to the use of converted salt water for irrigation purposes because there just isn't any information to support them. For instance, Mr. Jenkins' statement that converted Pacific Ocean water might be used in the Colorado River Basin by exchange completely overlooks project economics and the value of water for irrigation purposes. The committee's experience in analyzing economic studies of irrigation projects in the Colorado River Basin and elsewhere indicates that the use of converted sea water for agricultural purposes is unlikely in the foreseeable future except perhaps for extremely high value crops near the source of supply.

The committee concludes, then, that we still have a long way to go before general use of converted sea water becomes a reality and suggests to the Secretary of the Interior that, in these days when water is becoming more and more critical in many parts of the Nation, there is danger in raising false hopes that may contribute to a false sense of security and deemphasize the immediate need for conserving and making better use of the water we have.

The second and third purposes of the committee in holding these hearings were to determine if the views of the Department were consonant, with those of Congress as to the degree of urgency that should be given this program and to find out what measures were being taken to speed up the program in response to the congressional expression of urgency, set out in the act of June 29, 1955, and the related House and Senate reports. Notwithstanding the optimistic views of Department officials as to the outlook for early general use of salt-water conversion processes there was no indication that the Department attaches to the program the same degree of urgency which the Congress expressed 2 years ago, when the basic act was amended. At that time the conference committee of the House and Senate made clear its view that there was an imperative need for speeding up the objectives of the program and that it could not be allowed to drift along without producing concrete results. There have been no visible signs from the Department that it has taken cognizance of this expression of

Congress. The committee does not accept the lack of appropriations as an excuse and believes that funds made available are consonant with the program presented and that when the Department presents a positive and dynamic action program to Congress, designed to move in high gear toward accomplishing concrete results, funds therefor will be made available.

The fourth purpose of the committee's hearings was to determine if additional legislation was needed in order to speed up the program or meet its objectives at an earlier date. Mr. Jenkins stated that no additional legislation was needed at this time. He indicated however that authority for specific projects might be needed in 1 to 3 years. In view of the time required for enacting legislation and getting funds appropriated, and the time required to complete engineering work on specific projects before actual construction can be undertaken, the committee believes it might be wise to get the required legislation underway. For example, the committee believes 2 years could be saved in initiating large-scale testing of the Badger multiple-effect evaporator by enactment now of legislation to authorize the Secretary to work out a cooperative agreement and proceed with engineering work, but not actual construction, while the sealing tests are underway.

The committee does not wish to paint a dark picture to the American people with respect to the possibilities for finding ways and means for economically converting sea water to fresh water. On the other hand, the committee does not wish the American people to be misled as to just where we stand. The committee believes further that the Department is not attaching to this program the degree of urgency it deserves.

On the bright side of the picture, the committee was impressed by the testimony of Mr. Badger, and by the possibilities of the multiple-effect evaporation process he is developing. On the basis of information given the committee on this process, it would appear that authorization for large-scale testing should be obtained immediately, engineering design and other preconstruction activities should be authorized to proceed prior to the completion of the scaling tests, and the Department authorized to proceed with negotiations for plant construction with the idea of being ready to start construction immediately when the results of the scaling tests are known.

The committee believes that the need is for processes capable of producing large quantities of water and, in the committee's view, the development of small units of the type for use in individual homes, which Secretary Aandahl expressed interest in, has no place in this program. With the conversion cost from the Hickman still now estimated at $315 per acre-foot, this process seems to be moving in a direction away from "economic conversion."

Another process that appears to the committee to be impractical for large-scale conversion is the solar still. The committee agrees that this process may be usable in certain areas but it does not appear to meet the need for large-scale conversion for our seacoast industries and cities simply from the standpoint of the extent of the layout required. Information given the committee indicates that a 1-acre layout would produce about 5,000 gallons of water per day, which means that it would take about 47 acres to produce 1 acre-foot per day.

APPENDIX

Summary Statements From Annual Reports of Department of the Interior

(FROM 1952 REPORT)

SALINE WATER PROGRAM

Annual Report to the President and to the Congress

INTRODUCTION

This report is submitted in compliance with the provisions of Public Law 448, 82d Congress (2d sess.) that "The Secretary of the Interior shall make reports to the President and the Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act."

The act provides for the development of practicable low-cost means of producing from sea water, or from other saline waters, water of a quality suitable for agriculture, industrial, municipal, and other beneficial consumptive uses on a scale sufficient to determine the feasibility of the development of such production and distribution on a large-scale basis, for the purposes of conserving and increasing the water resources of the Nation.

The present report should be considered as of an interim character and covers activities in the program since enactment of the law, July 3 to December 31, 1952. Because the program is in the formative stage, program needs and requirements for additional legislative authorities will be better understood within the near future and the Secretary of the Interior who takes office on January 20 may desire to submit a supplementary report containing up-to-date information on the progress of the research program together with any specific recommendations for further legislation that appear desirable.

In accordance with the expressed desire of Congress in Public Law 448, maximum cooperation is being sought of existing Government agencies for coordination and direction of the work with heavy dependence upon private technical consultants in specialized fields of science. The actual research and development of low-cost processes is carried out by private interests.

The research to which the program is directed is divided into major related objectives as follows:

1. Conversion of sea water to beneficial uses, recognized as a long-term program with many ramifications.

2. Demineralization of brackish water, primarily for adaptation for agricultural and industrial purposes, which may well be a substantial step toward the development of economical means of converting sea water.

This report describes the establishment of the program, the progress of the work, and presents recommendations as to future actions. It will be appreciated that this is a new undertaking, the reporting period is short and time has been needed for activation and organization of the work. Achievements to date include the organization of the necessary groups and committees to carry out the required cooperation and coordination with Federal and other agencies; the carrying out of coordination activities with such groups; the compilation, publication, and distribution of a brochure designed to initiate a continuing survey of research as a basis of the program, containing a bibliography and discussion of all known or suggested processes and energy sources directly related to a process; the establishment of procedures for evaluating and processing research and development proposals, grants, and contracts; the placing of grants and contracts for development of processes; initial evaluation of several dozen proposed processes and a small amount of laboratory work to evaluate the apparent feasibility of specific research proposals.

Contacts have been made with numerous research groups, industrial concerns, and individuals having an interest in the program and in the stimulation of research.

Proposals are being received and evaluated. One grant has been made, and three other promising proposals are currently being negotiated as contracts. These include laboratory applications of ion selective membranes, small-scale development of solar heat, waste heat, and thermal difference evaporation studies, research studies into electrogravitational applications and preliminary investigation of a novel distillation process utilizing high-temperature steam.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., January 4, 1954.

The PRESIDENT OF THE UNITED STATES,
The PRESIDENT OF THE SENATE,
The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

SIRS: In accordance with Public Law 448, 82d Congress, 2d session, there is transmitted herewith the second annual report of action initiated and completed by the Secretary of the Interior in carrying out the saline-water conversion program.

Respectfully yours,

DOUGLAS MCKAY,
Secretary of the Interior.

ACTIVITIES IN BRIEF

The objective of the saline-water conversion program is to develop economically feasible processes for converting saline to fresh water. The Department of the Interior accomplishes this program by conducting research by means of federally financed grants and contracts, encouraging development by correlating and coordinating research efforts in this field, and encouraging other public bodies and private enterprise in research.

It has been fortunate that Federal funds have been available to initiate this saline-water conversion research. Even with the expenditure of Federal funds, research by private interests in this field has not been as extensive as had been expected. Every effort has been and is being made to encourage private research and to interest private industry in the development of processes. However, private interests, with a few exceptions, have not taken the necessary risks in the face of present limited technical knowledge on this subject.

In the initial research on process development, small expenditures have been adequate for exploratory and small-scale laboratory work. As processes are developed in the laboratory of sufficient promise field tests will be needed to determine feasibility on a large-scale basis. It is hoped that some of the field testing of selected processes can be undertaken soon to encourage greater interest.

Of the $400,000 appropriated by the Congress to this program for the fiscal year 1954, the Department has expended or obligated the following sums as of November 30, 1953.

Expended	$21,904
Obligated	63,474
Tentatively committed	223,640

The activities during 1953 have included: The development of procedures and methods of operation; the preparation of publicity directed toward making the program known to the scientific world; the engagement of consultants; the compilation and dissemination of information on demineralization processes and research activities; the convening of meetings and discussion groups under private and governmental agencies to further the objectives of the research; the contracting for research in a number of areas, with research work now underway.

This report consists of two parts: one dealing with the progress on federally sponsored research; the other relating to the coordination and exchange of information on phases of saline-water conversion research.

The Department's report for 1952 covered only the first 6 months of activity. It dealt with prospective avenues of approach, and set forth in some detail procedures for operation. This material is not repeated here except as necessary to report significant changes or progress.

As with any research into the unexplored, the chances of attaining the objectives of the program depend upon the extent to which genuine scientific interest can be enlisted. The chances of success depend to a large extent upon the scientific and engineering talent which can be applied to the research and develop-

ment work. The dissemination of accurate information on the scope and progress of the program is of essential interest to science. It is gratifying to report that a great many of the scientific and technical periodicals have been most cooperative in describing the program and its progress and in stimulating the interest of scientific and technical people. Although some scientists and engineers were at first hesitant to participate in the program, excellent cooperation by these groups now prevails and most of the known leaders in the field have offered their assistance.

As a first step in organizing a comprehensive program (in 1952) a compendium was prepared on existing and potential separation processes (physical, chemical, and electrical) including appropriate textual references. One possible solution to low-cost demineralization lies in the use, reuse, or conservation of the energy required in any applied separation process. Considerable attention was devoted therefore to potential energy sources which might be used. Inasmuch as solar evaporation, marine thermal difference, and other methods of demineralization depend upon the development of hitherto little used sources of energy, it is clear that a part of the saline water conversion program must be devoted to research in that direction. The need for permanence of water supply dictates that every effort be made toward the ultimate development of processes which require a minimum of nonrenewable resources. To this end much greater attention to these processes is indicated.

It was necessary to establish cost objectives, or criteria, for use in the development of economical processes. As the initial criteria, the maximum prevailing charges for undistributed municipal and irrigation water in the United States are used. Based upon a survey of the cost of water to 400 American cities the figure of $125 per acre-foot has been adopted for municipal water. For irrigation water $40 per acre-foot is used. For industrial water the cost varies greatly, and in many instances exceeds by several times the $125 per acre-foot established for municipal water.

Although ultimate success in developing economically feasible processes for large irrigation supplies cannot be precisely forecast, any significant reduction in the present minimum cost of demineralized water (about $400 per acre-foot for sea water by vapor compression distillation) must be viewed as substantial progress.

Research has indicated the possibility for a greater measure of success from the pursuit of certain lines of action. Already the research on two processes indicates a possibility of substantially reducing the cost of demineralized water in the near future. The distillation improvements and ion transfer membrane developments show both promise of successful application to particular phases of the saline-water conversion program, and the initial research is being continued. The possibility of the translation of one of these laboratory processes to field research can become a reality during the next year. Research involves trial and error and we are identifying certain processes which offer little prospect of success. These are being discarded.

The details of the contracts which have been entered into, the methods which have been tried, the advances which have been made, and the unprofitable avenues of research which have been demonstrated are summarized in succeeding sections of this report.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., January 5, 1955.

The PRESIDENT OF THE UNITED STATES.
The PRESIDENT OF THE SENATE.
The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

SIRS: In accordance with Public Law 448, 82d Congress, 2d session, there is transmitted herewith the third annual report of action initiated and completed by the Secretary of the Interior in carrying out the saline water conversion program.

Respectfully yours,

DOUGLAS MCKAY,
Secretary of the Interior.

Summary of Activities in 1954

The objective of the saline water conservation program is to develop economically feasible processes for converting saline water to fresh water. The Department of the Interior accomplishes this program by conducting scientific research and development by means of federally financed grants and contracts, encouraging such development by correlating and coordinating efforts in this field, and stimulating the interest of private and public organizations and individuals in the problem.

Progress during the year has further demonstrated the need for a central governmental program of this nature having no interest in the development of one industrial process over another. Few industrial firms appear to feel justified in carrying the development of saline water conversion equipment further than improvements in present equipment. However, to reach the ultimate objective of the program—demineralized water in large quantities at a small fraction of present costs for the general economic benefit—more than minor improvements in processes are needed, however advantageous the equipment might be made by such improvements. The governmental program assures that research and development will be continued persistently, including minor local improvements in processes, until in time low-cost water in large quantities is available to the general public.

Every effort is being made to encourage private development of processes, and as a result a few industrial firms have undertaken independent research in this field during the past year, and wholehearted cooperation has been received from several organizations now engated in these activities.

During 1954 new light has also been cast upon the direction which the program should take in the development of unconventional energy sources for demineralization. The irreducible quantity of energy required for extracting 1 acre-foot of fresh water from sea water is about 900 kilowatt-hours. It has been estimated that the minimum amount ever to be reached in practice will probably be 4 to 5 times that quantity. Thus the energy cost alone will not be less than about $40 at 1 cent per kilowatt-hour, $20 at 5 mills. The amortized cost of equipment and the cost of operation will probably at least equal the energy cost. (The costs are generally less for brackish waters.) Thus it becomes important that nonconventional low-cost energy such as solar energy, wind power, geothermal energy, etc., be explored vigorously and exhaustively in connection with process development and use.

In the initial research on process development, small expenditures have been adequate for exploratory and small-scale laboratory work. As the processes being developed in the laboratory show sufficient promise, field tests become necessary to determine feasibility on a large-scale basis. Such field testing of one process on brackish waters was started in December 1954 and field tests of a very promising sea water process are expected during 1955. Such field tests on a pilot plant scale are a necessary part of any process development, and are more expensive than the original research.

However, as the disparity between present costs of converting salt water and the program objective costs is large indeed, it is necessary to pursue diligently every genuinely promising development or basically sound idea. Furthermore, since it is highly improbable that a single process will provide freshened water for all purposes at all locations under all circumstances, it is desirable that several different principles and combinations of processes be under development concurrently. Thus, considerable attention is devoted to new, or "seed," research ideas and to programs designed to generate such new ideas.

At the beginning of the program, the cost of converting sea water to fresh water by the best processes in use was estimated at about $400 to $500 an acre-foot. Accordingly 2 arbitrary criteria were set for the initial 5-year phase of the program, one for water for municipal and similar purposes and one for irrigation water. For these criteria no distinction is made as to whether the water to be converted is sea or brackish water. These goals were $125 and $40 per acre-foot (38 and 12 cents per 1,000 gallons) respectively and they were believed, on the basis of data then available, to represent about the maximum that could be borne by these types of use. It was thought that if these goals could be approached during the initial 5-year phase, further reduction could be justified in a second phase.

Increased emphasis is being placed on the potential use of demineralized water for industrial purposes, and a survey of such uses is being initiated.

The work accomplished so far indicates that attainment of the first goal of winning fresh water from sea water at a price which municipal users and some

industries might pay, and the conversion of brackish water to irrigation uses, seems to be in sight although much work will be necessary before either can be brought to realization. The task of converting sea water for irrigation is more difficult but the researches continually produce new ideas and one of these may well point a way to its attainment, and it is clear that low-cost nonconventional energy must be developed.

The 9 eminent members of educational, scientific, and industrial organizations who, at the beginning of the program, agreed to serve as advisers to the Secretary on broad-policy matters, held one meeting of 2 days in April 1954 at which all procedures and progress were thoroughly examined. The recommendations of that group are given on page 39 of the appendix. All of the original advisers are continuing to serve in this capacity. They are: Dr. Robert G. Sproul, president, University of California, Berkeley; Dr. Lee A. DuBridge, president, California Institute of Technology; Dr. George D. Humphrey, president, University of Wyoming; Dr. Louis Koenig, associate director, Southwest Research Institute; Mr. Henry J. Schmitt, editor and publisher; Mr. J. J. Cronin, vice president, General Motors Corp.; Dr. Frederick L. Hovde, president, Purdue University; Mr. Sheppard T. Powell, consulting engineer; and Dr. James R. Killian, Jr., president, Massachusetts Institute of Technology.

This report consists of three parts and supporting appendix. Part I deals with the progress on federally sponsored scientific research and development; part II relates to the coordination and exchange of information on phases of saline water conversion; part III concerns the need for further legislation, as required by statute.

The Department's report for 1953 covered the work to November 15, 1953. It dealt with work in progress under various contracts and grants, and described the field to be investigated by each contractor. Some of these investigations have now been completed and the results obtained can be described. In the other cases, where work is still in progress, it is now possible to give some account of accomplishments up to November 15, 1954. These results and accomplishments are described in some detail in this report.

During the year 39 proposals for research were evaluated formally and several dozen additional suggestions were considered. Eleven new research and development contracts were let. Work under 11 other research contracts initiated earlier was completed with affirmative results definitely justifying further research on 8. Two processes give promise of converting sea water at less than half present costs, and one for brackish water has reached pilot-plant stage and is being field tested. Information has been obtained and exchanged on developments in this field in the United States and more than a dozen other countries from Europe to Australia.

Interest in the need for saline-water conversion has been stimulated and a number of private organizations in this country and abroad have initiated independent research. As the authorized central Federal agency in this field, the Department of the Interior has coordinated all activities in this field, both public and private, to the greatest extent deemed appropriate and has coordinated its work with the Department of Defense and seven other Federal agencies.

The valuable assistance of the advisory group and the wholehearted cooperation of the many individuals and organizations in the United States and the several foreign governments who are cooperating are gratefully acknowledged.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., January 3, 1956.

The PRESIDENT OF THE UNITED STATES.
The PRESIDENT OF THE SENATE.
The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

SIRS: This report on the activities of the Office of Saline Water during 1955 is made in accordance with the provisions of the Saline Water Act of July 3, 1952 (Public Law 448, 82d Cong., 2d sess., as amended), which requires that "The Secretary of the Interior make reports to the President and the Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act."

The year just closed has brought increasing indications of shortages of fresh water throughout many parts of the United States as well as other regions of the world. Numerous communities in the eastern part of the United States are seeking for adequate water sources to serve their growing populations in the face of over-

taxed supplies and increasing pollution of streams and other waters. Growth of communities in the western part of our country is restricted by lack of water sources free from excessive saline contamination.

Thus, the search for economical means of demineralizing saline water has become a timely and urgent matter. All evidence emphasizes the importance of research in this field and the wisdom of the Congress in making provision 4 years ago for encouraging such research, and in extending the scope of the act during 1955. This Department has been active in prosecuting the work. The researches initiated in 1953–54 have been accelerated and all final results have been made available for public use. Eight research reports have been published, four of them during the year.

The saline water research program is primarily one of cooperation with private groups. The Department carries out this cooperation by (1) stimulating the interest of private and public organizations and individuals in the problem and coordinating activities in this field, and (2) conducting scientific research and technical development through grants and contracts with individuals or institutions.

Several private equipment manufacturers and scientists, including a number of the research contractors, have devoted a measure of financial support to improvement of conversion processes during the past year. It is hoped that as the processes reach more advanced stages of development, equipment manufacturers in particular will be justified in undertaking greater financial responsibility.

Under the original law the research facilities of Government agencies could be used only for advisory service, but the 1955 amendment has given limited authority for utilizing them in research and developmental work, which already has begun. Similarly, the specific new authorization to employ the abilities of outstanding scientists in foreign lands on this worldwide problem now enables full use to be made of cooperative international research, on which limited participation was begun in 1953.

The present plan of operation has demonstrated certain advantages over an exclusively governmental program of research, as shown by the extent of the research that has been conducted and by the number and caliber of the scientists who are participating in the program. During 1955 initial use has been made of the 1955 amendment; two Government research laboratories are now taking part in the program. It is anticipated that this type of research assistance will prove increasingly valuable.

It is recognized that the problem of saline-water conversion is essentially a matter of reducing the cost of the water produced, whether accomplished by new processes or by improvement of existing processes. Technically feasible methods of producing fresh water from either sea water or brackish inland waters have been known for many years, and are practiced on a large scale in various arid regions, but the cost of the water produced is far too high for general use. The researches to date indicate gradual progress toward low-cost production. Estimates of the probable cost of large-scale conversion of sea water show that it is approaching the maximum existing costs of municipal water in the United States and is considerably below those of industrial water, although still several times higher than those of currently used irrigation supplies. At the same time economical improvement of brackish waters for many irrigation uses, which is inherently less expensive than conversion of sea water, is definitely in sight.

The gap between present conversion costs and those being sought is being steadily narrowed by new processes and improvements in old processes. One instance of this lowering is the demonstration that heat transfer in distillation processes can be increased fivefold to tenfold by improved plant design, with important influence on cost. Another is the potential efficiency and low cost which may be achieved by electric membrane processes. Various osmotic processes and solar distillation also offer promise of efficient production.

It is appropriate to emphasize here that saline-water conversion involves practical problems in addition to the scientific and technical problems that are the immediate subjects of research. Among them is the fundamental difference between fresh-water production at the seacoast, where the ocean can serve as a source of raw water and also as means of waste disposal, and inland production from brackish water, where it is necessary to deal with the difficulties of variable demand and distribution as well as disposal of the residual salts or concentrated brines. These difficulties, which complicate inland purification, may call for some modification of the research program from time to time. In the main they are matters to be worked out in the course of individual process application.

Effective prosecution of the research may require the provision of experimental facilities at a seashore site for field testing of pilot-plant desalting equipment and other research, where a large continuous supply of natural sea water is available.

During the year the group of eminent leaders of scientific, educational and industrial organizations who advise me on the broad aspects of the program provided valuable information which was used by the Congress in support of the amendatory legislation, and in other ways aided the program materially. The generous assistance of this group and that of the many other persons and organizations who have contributed to the program is gratefully acknowledged.

The basic authorization, as amended during 1955, appears adequate for present requirement. Therefore no recommendation for further amendatory legislation is made at this time.

In summary, I am pleased to report that the great potential value of a successful solution of the problem in relation to the moderate expenditures involved, together with the results achieved so far, clearly justify the accelerated prosecution of the work as urged by the Congress and as carried on by this Department during the year just closed.

Respectfully yours,

DOUGLAS MCKAY, *Secretary of the Interior.*

SALINE WATER CONVERSION REPORT FOR 1955

SUMMARY OF ACTIVITIES

GENERAL

During the past year the Department vigorously prosecuted the program of research and development and that of coordination and exchange of information in the field of low-cost production of fresh water from sea water or brackish inland waters to which the Saline Water Conversion Act of 1952 is directed (Public Law 448, 82d Cong., 2d sess.; for text see appendix). The progress heretofore reported led to an amendment at the 1955 session of Congress which extends and broadens the act and provides considerable increase in the scope of the program (Public Law 111, 84th Cong., 1st sess.; see appendix).

Principal provisions of the amendment are: (1) The 5-year program is extended to 11 years, fiscal years 1953 to 1963, inclusive, with limited extension for 3 additional years; (2) the total authorized expenditure for the 14 years is increased to $10 million; (3) use of the facilities of Federal scientific laboratories, heretofore not allowed, is authorized to a total cost of $2,500,000; (4) expenses for administration and coordination are limited to $2 million; (5) authority is granted to expend up to 10 percent of each year's research funds in foreign countries, for the development of processes useful to the program in the United States; and (6) cooperation with the Atomic Energy Commission and the Civil Defense Administration is specifically authorized.

The significant expansion of the program authorized by the amendment made it possible to extend 1955 activities materially beyond the previous limits. Among other things, it became feasible, budgetwise, to contract for construction of a distillation apparatus of medium size for pilot-plant testing of Dr. K. C. D. Hickman's vapor-compression process, and to plan other pilot-plant field tests for future years. Cooperation with the Atomic Energy Commission and the Civil Defense Administration, provided in the amendment has been accelerated. Several cooperative research undertakings abroad are pending. The staff in charge of the contract and coordination work has been increased by addition of three. Also, making use of the new authority to invite Federal laboratories to participate in the research work, an agreement for research and testing has been entered into with the National Bureau of Standards for fundamental study of membranes having selective permeability, and limited laboratory work on the electric membrane demineralization process has been arranged for with the Bureau of Reclamation.

The 1955 amendment facilitates the purposes of the original act.

ORGANIZATION

In carrying out the expressed intention of the Congress that the program be accelerated, a functional analysis was made of the staff organization and the operations of the advisers and the departmental committee. As a result of that analysis the staff organization has been strengthened to conform to its broadened responsibilities. It was recognized that during the preceding 3 years the program

had been in the exploratory research phase, that it is now moving forward toward the pilot-plant phase, and that the resulting larger scope of its operations and the increase in workload could better be met by an improved organization.

Accordingly, the program was reorganized as an Office, continuing as before within the Office of the Secretary, and headed by a director reporting to the Assistant Secretary for Water and Power Development. As reorganized, the Office comprises three branches, dealing, respectively, with research, engineering development, and coordination and stimulation of private developments in this field.

Although the Secretary's advisers on saline water were not called into session during the year, they took an active part individually in providing information used by the Congress in support of the amendatory act. The group continues to assist the Secretary in determining the proper line of development of the conversion program and giving general direction to the broad planning of the research and development work. Assistance to the program was given also by the departmental committee.

PROCESS RESEARCH UNDER DEPARTMENT SPONSORSHIP

The progress of work under the Saline Water Conversion Act is indicated by the fact that more than 500 research proposals have been received, and to the end of 1954 the Department had executed 22 contracts in support of research and development projects found promising. With few exceptions the contracts call for specific performance, and their duration generally is for a year or less. During 1955 8 additional contracts were entered into, bringing the project total to 30. They include a wide range of investigations in scientific and engineering fields.

As some of the researches approached completion, certain of those which were partly or wholly successful were extended by supplemental contracts for additional research. In all, 25 projects were in progress during part or all of the year. The research work has been conducted in various fields of physical processes and phenomena, as follows:

Type of process:
- Thermal distillation:
  - Vapor-compression
  - Compression and multiple-effect
  - Critical-pressure
- Solar distillation:
  - Single-stage, roof-type still
  - Inclined glass still
  - Plastic-covered still
- Electric membrane separation:
  - Electrodialysis cell development
  - Membrane synthesis
  - Fundamental membrane research
- Osmotic processes:
  - Pressure osmosis
  - Air-film osmosis
  - Osmionic process
  - Adsorption osmosis
- Solvent extraction of water
- Separation by freezing:
  - Countercurrent washing of ice
  - Compression separation
  - Zone freezing
- Other processes:
  - Ultrasonic vibrations
  - High-frequency currents

Major results

(1) *Coordination and stimulation of research and developmental work.*—The principal objective of the saline-water activity as authorized is to stimulate research and development of conversion processes. This primary coordination or stimulation activity is supplemented by the program of Government-sponsored research. During the year direct coordination activities, exclusive of the governmental-sponsored research, included numerous private developments in the United States and abroad, as described in some detail in the chapter "Coordination Activities" of this report.

Briefly, four cooperative international researches were begun in Europe in the fields of electrodialysis, scale prevention, solar distillation and ion-exchange; throughout the world more than a dozen solar energy researches bearing on distillation were under way; a number of major American industrial firms initiated engineering investigations of new distillation cycles; numerous local governments undertook surveys and other investigations of saline water resources; one American and several foreign industries installed salt water conversion plants of existing design; and a host of public and private organizations and individuals sought to cooperate in process developments by offering personal services, sites for plants, and technical services and facilities.

The numerous governmental agencies, including the Department of Defense, Atomic Energy Commission, Department of Agriculture and others, proceeded with related work and freely exchanged results with the Department. Only in one—the most vital field—were the tangible results disappointing, namely, in the receipt of a significant number of sound, meritorious new scientific proposals for process improvements. Clearly, a greatly accelerated program of idea stimulation is needed in 1956.

(2) *Departmental sponsored research grants and contracts.*—The 1955 research and development work sponsored by the Department brought substantial progress. Exploration of possible demineralization processes advanced several of them nearer to the requirements of practice, while it revealed the lack of feasibility or practical promise of a number of others.

Outstanding among the year's developments were those in the fields of vapor-compression distillation and electro-osmotic membrane separation. Osmotic processes as a whole were given much attention, as was solar distillation. Other items of progress include better knowledge of water extraction by organic solvents, by pressure osmosis, and by freezing.

Distillation processes reached the point of design and initial construction of a small pilot-plant still of vapor-compression type, to have a capacity of 25,000 gallons per day. High heat-transfer coefficients were attained under nonscaling conditions by low-temperature evaporation of thin films of water projected at high velocities. High coefficients were realized also in studies of high-velocity flow with turbulence.

Design and cost studies of various distillation cycles were completed, including a combination of vapor-compression and multiple-effect distillation, with indications that appreciable cost reduction is possible. However, the importance of evaporator scale control was again demonstrated by the tests. Investigation of distillation in the supercritical range, at high pressures and temperatures, indicated that this process also has practical possibilities if scaling and corrosion can be overcome.

Solar distillation research was carried on by three investigators. It included extended study not only of glass-roofed cells but also of cells formed of plastic sheets as the vaporizing and condensing chambers. Plastics to date have proved less effective than glass. An experimental glass-covered pilot-plant solar still of 1-acre size, which is expected to yield fresh water at average rate of from 5,000 to 7,000 gallons per day, has been proposed.

One version of the electric membrane process was the subject of a small pilot-plant study during year, under contract entered into in 1954. This pilot plant, a mobile unit, operated on brackish irrigation and municipal waters in extensive field trials in Arizona and South Dakota. Further study of experimental membrane processes is being conducted under six different researches.

Osmotic flow under high pressure through cellulose acetate films proved to have promise in producing fresh water from sea water. Another investigator showed that the driving force caused by the concentration difference between brine and brackish water can be used to demineralize water by means of an assembly of permselective membranes.

In continuation of the previous year's work in extraction of pure water from saline water by an organic solvent, more than 100 solvents were screened. Salt removal by freezing was under investigation by three researchers. To overcome heavy entrainment of salt water in the ice, repeated washing of the ice in countercurrent mixing sequence was tried, as were draining, centrifuging and compression. A process of purification by zone freezing is being investigated.

Condensed reports on individual researches are presented later in this report.

OUTLOOK FOR THE FUTURE

Broadly, the year's researches pointed to a number of future possibilities and prospects:

(1) Distillation shows much promise of attaining considerably lower cost levels. It is anticipated that expansion of development work to fullest utilization of very high heat-transfer rates will be productive. Combination processes within the normal temperature range of distillation, as well as work in the critical range of salt water, also require further study. Scaling has proved to be a formidable difficulty. For research into both distillation and scaling control, experimental work on actual sea water at a seashore location is essential.

(2) The performance of membranes, both electric and osmotic, is noteworthy and justifies continuing support. The investigations of the past 2 years reveal the possibility that fuller work in both laboratory and pilot-plant research will result in greatly improved performance and lower water costs.

(3) Developments in solar distillation are encouraging, and warrant additional work to bring this means of utilizing low-cost energy nearer to practical serviceability.

(4) Freezing processes have inherently low cost if a rapid and economical method of separating the pure ice from the mother liquor can be developed.

In addition, it is apparent that the several processes not yet fully explored, including chemical, physical and electric, need to be followed to definite conclusions.

A growing need exists for a small desalting unit of household size for the many seashore homes and cottages in the United States, irrigation of small truck farms along seacoasts in many parts of the world, for improvement of farm water supplies, and for possible civilian use in emergency conditions. The Department has encouraged and stimulated development of small desalting units and several equipment manufacturers are exploring the feasibility of adapting such processes as the Hickman still and various membrane devices to these uses.

COSTS AND COST ESTIMATES

While the 1955 work demonstrated that development of low-cost conversion methods is making progress on laboratory scale, accurate translation of the results to plant-scale dimensions and precise production-cost figures is not feasible at this time. In general, it must await pilot-plant testing and the design of full-scale production plants as basis of estimate. Production-cost estimates contained in the individual project reports, on later pages, are those of the researchers or investigators and must be presumed to reflect the optimistic views natural to a proponent.

The most promising processes so far developed appear to be able to produce fresh water at costs comparable with the maximum present costs of industrial water supplies. Such maximum costs, however, prevail only under exceptional conditions of service, and any extensive use of freshened saline water is dependent on reducing present production costs.

It is clear that a number of years of intensive effort will be required before a cost level can be attained that will make converted saline water economically available for most purposes. However, pilot plants will have to be built and operated before water costs can be realistically determined.

The pilot-plant vapor-compression still now under construction is believed to be one necessary forerunner of other pilot plants from which the conditions and costs of practical production by that process can be determined with fair reliability. Construction of a medium-size pilot plant solar still has been proposed and is under consideration. The past year's operation of the pilot-plant electric membrane field-test installation, while in many respects highly encouraging, disclosed difficulties of the type likely to attend any operation of the kind, such as lack of definite determination of maintenance costs, and unknown production costs of a plant of working size. A larger and improved plant may have to be built and operated to furnish a basis for reasonably definite estimates.

In view of the vital importance of the cost factor to the practical application of demineralization, and the variety of cost-estimating methods and assumptions used by various manufacturers and investigators, attention was given during the year to the problem of standardizing cost determination. The development of a code of basic data and assumptions was initiated and well advanced during the year.

A special problem arises in comparisons between the cost of converted water and the cost of diverting and supplying naturally fresh water. Many estimates

of the cost of supplying fresh water, particularly for large irrigation projects, necessarily include modifying assumptions that operate to reduce the actual overall costs. It is evident that in any comparisons, care must be taken to use only real total costs.

SPECIAL PROBLEMS OF SALINE-WATER CONVERSION

Translation of processes for demineralization of saline waters to large-scale service presents some practical questions distinct from the scientific and technical problems included in the research studies. Brief reference to three of these is appropriate here.

Sea water and inland conversion

The essential differences in governing conditions between seacoast and inland locations for conversion plants, and the fact that some processes are better adapted to one than to the other location, suggest that conversion processes should be divided into two distinct groups. On present showing, distillation processes are well adapted to seacoast use, while selective-membrane processes seem better adapted to inland regions. It appears probable that economy may favor large central plants at seacoast sites and relatively small local-service plants at inland sites, although both large and small units will be in demand in both locations.

Byproduct disposal

Costs and operating systems of demineralization will be complicated by the problem of waste disposal at inland plants. In the case of certain processes, the value of byproducts produced at the conversion plant may tend to reduce the water cost. Similarly, under certain conditions, byproduct power generated by steam used for process heating may have market value. On the other hand, in inland areas the problem of waste disposal will require considerable study and may increase costs materially.

Hard waters

The organic act clearly relates to the development of means for producing suitable water from saline waters, without restriction as to the kind of treatment. It is true that the Department's research work to date has been concerned largely with demineralization or the removal of salt from water. However, the extensive occurrence of various substances that cause hardness in water suggests that improvement of means of water softening may be a valuable associated or separate result of the research investigations.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., January 11, 1957.

The PRESIDENT,
The White House, Washington, D. C.

MY DEAR MR. PRESIDENT: This report on saline-water conversion for the year 1956 is made in accordance with the provisions of the Saline Water Act of July 3, 1952 (Public Law 448, 82d Cong., 2d sess., as amended), which requires that "The Secretary of the Interior make reports to the President and the Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act."

The annual reports for the formative 3 years of the program, 1952 to 1954, included considerable description of the organization of the work, the research and coordination procedures adopted and the initial exploratory and cooperating research. For the year 1955, the fourth annual report summarized these activities and presented considerable detailed description of processes being developed, and of the coordination and stimulation of private research in this field. Although significant progress has been made during 1956, much of the work for this year has consisted of continuation of that begun earlier and now reaching intermediate phases. For that reason, and in light of the limited staff available for the activity, this letter report has been prepared for 1956. For those interested in greater detail, this letter, together with the report of the Director of the Office of Saline Water now being prepared, present a summary of progress in saline-water conversion.

The water shortages in the United States and other regions of the world are continuing to increase. Fortunately, appreciation of the seriousness of these

shortages is also increasing, and the public is becoming aware of the need for protection and conservation of all existing water resources as well as development of entirely new water sources, such as through saline-water conversion. In the western part of our country, the accelerated development of the Colorado River, recently authorized by the Congress, is already emphasizing the vital potential effect which successful large-scale sea water conversion developments would have upon nearly all western areas. Scarcely a State within or bordering the vast Colorado River Basin would not benefit from an unlimited supply of converted sea water in the Pacific and gulf coastal areas, either directly or through exchanges of water.

During the early months of 1956, before a small supplemental appropriation was made under the expanded authority enacted in 1955, planning for increased activity was carried out. Although the supplemental appropriation made in May 1956 was put to immediate use, the expansion of activity was reduced with the beginning of fiscal year 1957, as the appropriations were cut back slightly. However, continued planning for the expanded program anticipated during fiscal year 1958 is underway and all available funds are being put to maximum productive usefulness.

The saline-water research program is primarily one of cooperation with private groups. The Department carries out this cooperation by (1) stimulating the interest of private and public activities in this field, and (2) conducting scientific research and technical development through grants to and contracts with individuals or institutions, and in governmental laboratories.

During the first 3 years of the program, the processes and phenomena originally presented in the Department's brochure, Demineralization of Saline Waters, were developed through voluntary proposals submitted to the Department. Stimulation of interest and proposals was achieved through distribution of that brochure and through technical, semitechnical, and lay publications. Thus, private scientific organizations were depended upon to provide a sufficient reservoir of ideas to assure that all processes were investigated and that all Federal and private funds available for this purpose were used efficiently.

More recently, as the flow of ideas and voluntary proposals diminished, and some proposed processes were eliminated, the small Government staff, through its familiarity with all of the work and needs, has been formulating plans for further investigations, which are now being presented to operating research groups.

The provision of the 1955 amendment which gave limited authority for work in Government laboratories is proving beneficial. Work is under way in the laboratories of the Bureau of Standards and the Bureau of Reclamation in fields bearing upon membrane and distillation processes.

Although direct financial cooperation abroad as provided by the 1955 amendment has not been initiated, cooperation through exchange of information with foreign research is active, and limited financial cooperation on several projects which will be beneficial to the program in the United States is under consideration. More than a score of active research and development undertakings have been initiated by governmental and private interests in other countries, most of which are cooperating to some extent with the Office of Saline Water of this Department

With the development under the Government program of several processes not heretofore exploited for this purpose, the interest in undertaking work in this field by private industrial organizations has increased somewhat during the past 12 months. Largely because of the stimulus being given to the problem under the present program, a number of private equipment manufacturers have reported research activity and development in this field and have initiated cooperation with the Department. In addition, several universities are carrying out basic and applied research in fields related to saline-water conversion.

During 1956, 15 research undertakings were completed. Of these, 10 justified further research and development work. In addition, 12 new research projects were started and 2 cooperative agreements with industrial organizations on saline-water research were executed. Three medium-size pilot plants are being constructed which will require field testing during 1957. During the year, 83 research proposals were examined and a backlog of 15 research projects awaits appropriations and subsequent negotiation of contracts. Some of these may not materialize because some of the proposed investigators will undoubtedly be engaged in other work by that time.

With the development of some processes to the pilot-plant stage as at present, it has become increasingly necessary that facilities be provided at a seashore location where extended testing and improvement work under the direction and supervision of Government representatives can be carried out. Although a number of governmental laboratories, such as those of the Bureaus of Standards, Reclamation, Mines, and others are available where certain research can be con-

ducted, they do not meet the essential requirement of being near a continuous supply of natural sea water. Thus, it has been found necessary to seek temporary test facilities of industrial firms at scattered seashore locations where pilot-plant work of this nature can be conducted. However, borrowed facilities are not the best means for most effectively carrying out the development work and should be considered as a temporary expedient. The ultimate need for a test and evaluation center at a seashore location was recognized from the beginning, but although the present authorization is believed to be sufficiently broad to include such a facility, specific appropriations for that purpose have not been available.

Data are available from which reasonable estimates of future irrigation and municipal requirements for converted saline water can be projected. However, information on the quantity, quality, location, timing, and permissible cost of converted saline water needed for industrial uses is almost entirely lacking. Since industrial uses probably will be the first widespread applications of conversion processes, a survey of industry's needs for saline water conversion remains a definite need of the program; plans are being made to initiate such a survey in the near future. Several of the major industrial firms interested in this development have inquired as to the market for conversion equipment and expect the Department to have conducted such a market survey. In addition, a survey conducted by the appropriate organization, covering all end uses, all types of saline waters, in all parts of the world, would be helpful, both to such firms and to the Office of Saline Water. Similarly, surveys of the location and extent of brackish waters being carried out State by State by the Geological Survey are expected to provide valuable information needed in the planning of process development by the Office of Saline Water.

Progress during the year on several conversion processes shows continued improvement in factors affecting low-cost production. Several improvements in distillation processes have been developed and, if intermediate research and pilot-plant work now started is successful, it appears reasonably certain that costs of large-scale distillation of saline water will be reduced to $0.50 or less per 1,000 gallons in the near future. Improvements in solar distillation, consisting of both increased production rates and reduced capital costs, show rather clearly that water may be produced by these processes in areas where the climate and other pertinent factors are favorable, at costs comparable with the cost of other distillation processes. Developments in improved freezing processes for separating salt from water also appear promising and one contract research program is under way which offers promise of producing water at between $0.50 and $1 per 1,000 gallons. The various electrochemical and osmotic processes which appear more suitable for treatment of brackish waters are advancing very satisfactorily, both in this country and abroad, and the results of field testing of one membrane process have provided valuable information by aid of which further major improvements are now being undertaken.

During the year, the group of eminent leaders of scientific, educational, and industrial organizations, who advise me on the broad aspects of the program, provided valuable information which aided the program materially. Similarly, the outstanding scientists and companies serving as consultants to the program have been responsible for much of the success achieved so far. The generous assistance of these groups and that of the many other persons and organizations who have contributed to the program is gratefully acknowledged.

The basic authorization, as amended during 1955, appears adequate to meet present requirements. Therefore, no recommendation for further amendatory legislation is made at this time. However, depending upon the results of field tests of several processes obtained during the coming year, it is possible that a recommendation may be made next year for legislation to authorize construction of one or more large pilot plants, the cost of which could easily exceed the present average rate of authorized appropriation.

In summary, I am pleased to report that significant progress within the limits of appropriations has been made during the year, both in reduction of costs of existing conversion processes and in development of phenomena and processes not heretofore utilized commercially. I feel certain that with continued Executive and congressional support of the program as authorized by the Congress, further significant progress and development will be accomplished during the year 1957.

Sincerely yours,

FRED A. SEATON,
Secretary of the Interior.

NOTE.—Identical letters were submitted to the President of the Senate and the Speaker of the House of Representatives.

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